I Am ALTREP (And So Can You!)

Gabriel Becker, Work Joint with L Tierney, M Lawrence and T Kalibera

The Year: R v0-3.4 (1997- 2018)

You Know What The R C API Needs?

~ Me probably, circa 2016

An R Vector Viewed From C

Two primary sections

- SEXP header

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  - The values of the vector elements

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Atomic vector objects were *tightly coupled* with their data

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- payload data in simple array format

An Incomplete History of (Not) Duplicating Data in R $< 3.6.0$

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  - Duplicate then, and only then

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This Worked Well, Obviously

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- Full duplication on modifying of atomic vector attributes
- No way for vectors to retain information about themselves
  - Sortedness, presence of NAs, etc

The Idea of ALTREP

Atomic Vectors, By Way Of

Design Intent

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- Implement "Smart Vectors"
- Decouple data and attributes
- *Completely transparent* at the R level

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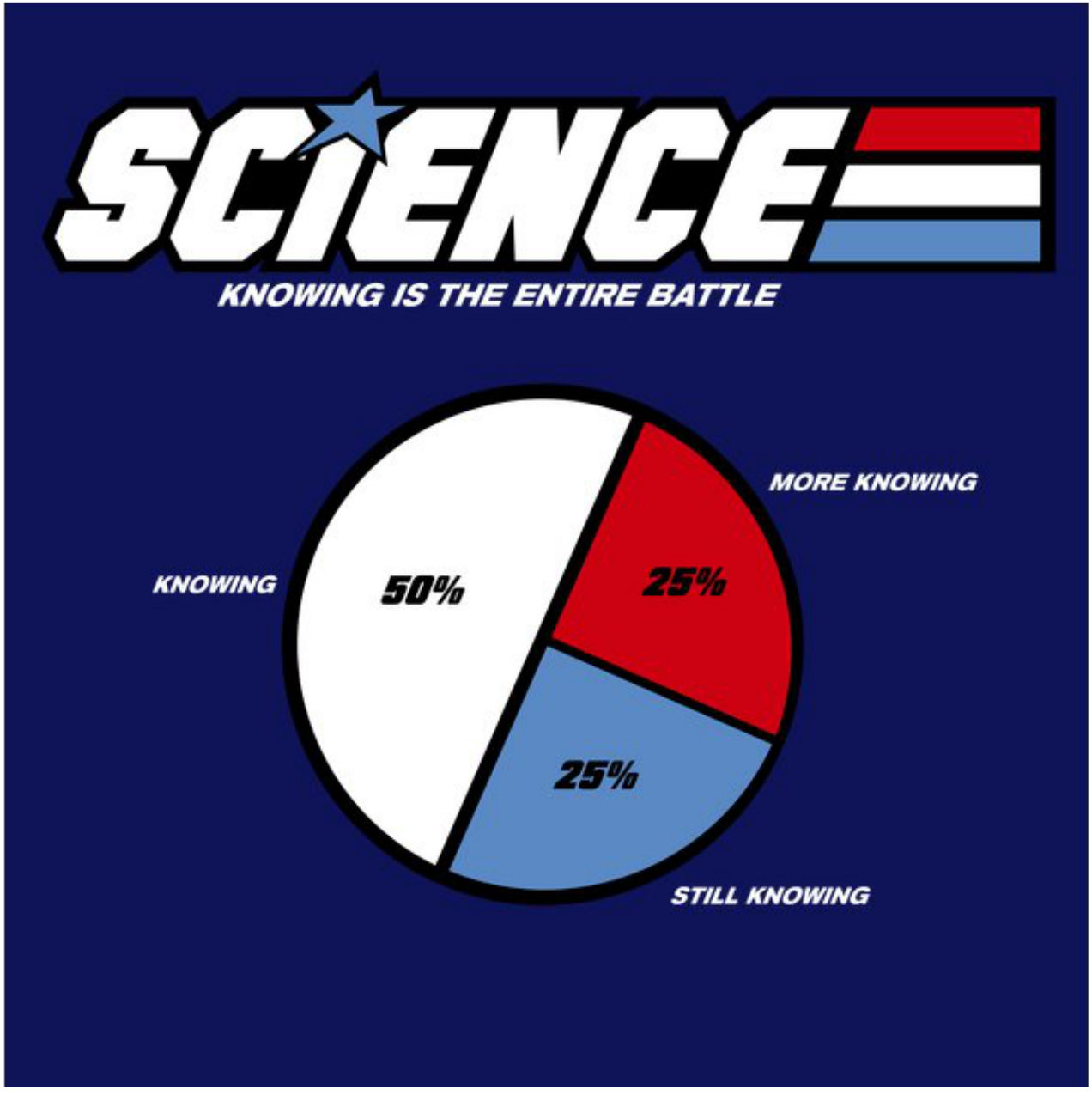
  - Efficient representations
  - E.g., compact integer/real sequences

Smart Vectors



Smart Vectors

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- **Fully compatible with R internals**

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  - Implemented by Luke for 3.6.0 for vectors $>$ certain size

How to Spot an ALTREP - R Code Edition

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  - exception: hooks to call ALTREP methods

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  - Compatible with R internals

The Deets

ALTREP

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  - `SETALTREP(x,v)` not provided ... don't do that

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- Currently Implemented as CONS cells, **but this may change without warning**

How R Internals Interact With Vectors

Overview

- Access data (payload)

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- Remember, ALTREPS should be passable to all R internal functions

Select ALTREP Class Methods

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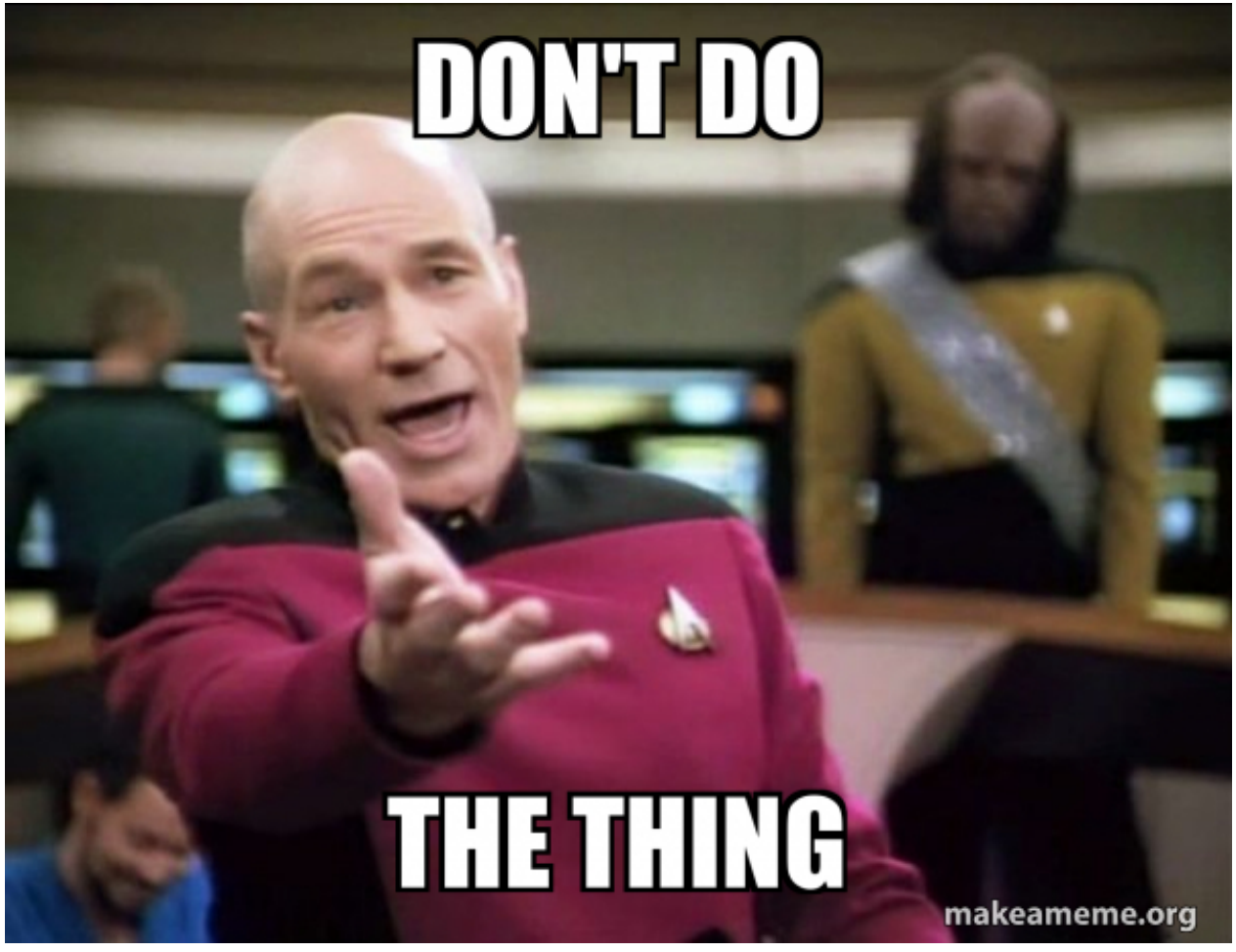
- Don't define `USE_RINTERNALS`

If Someone on R-Core Tells You Not To Do Something in C Code



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  - Often just duplicate into std SEXP vector and use that from now on

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  - pointer to full data array

Elt

- `int Elt(SEXP x, R_xlen_t i)`

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  - Return *value* of vector at single position

Sortedness in ALTREP

```
enum {SORTED_DECR_NA_1ST = -2,
      SORTED_DECR = -1,
      UNKNOWN_SORTEDNESS = INT_MIN, /*INT_MIN is NA_INTEGE
      SORTED_INCR = 1,
      SORTED_INCR_NA_1ST = 2,
      KNOWN_UNSORTED = 0};
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  - `KNOWN_UNSORTED` ***only*** if vector has $>$ 3 distinct values
  - **and is not sorted in either directoin**

Creating ALTREP Class

```
static void InitVWindowRealClass(DllInfo *dll)
{
    R_altrep_class_t cls =
    R_make_altreal_class("vwindow_real", "vectorwindow", dl

    /* ALTREP methods */
    R_set_altrep_Inspect_method(cls, vwindow_Inspect);
    /* etc */

    /* ALTVEC methods */
    R_set_altvec_Dataptr_method(cls, vwindow_Dataptr);
    /* etc */

    /* ALTREAL methods */
    R_set_altreal_Elt_method(cls, vwindow_real_Elt);
    /* etc */
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  - Mark things as not-mutable to get read-only shared access to memory

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- Write functions/macros which abstract details of whats in data1/data2
  - Always use those even in your own methods
- Do not write C code which calls `R_altrep_data*` or **especially** `R_set_altrep_data*` outside of ALTREP methods

R Internal Data Access API

Accessing the Data

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- (*) `INTEGER_RO` - returns `const` pointer
- (*) `INTEGER_OR_NULL` - returns `NULL` pointer if ALTREP "prefers not to" populate full data array

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- `INTEGER_RO` and `INTEGER_OR_NULL` prevent this destructive access
  - Should be used in your C code where possible

Retrieving Partial Data

- (*) `INTEGER_ELT` - return c value (`int`, `double`) for single data element

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- (*) `INTEGER_ELT` - return c value (`int`, `double`) for single data element
- (*) `INTEGER_GET_REGION` - populate provided buffer with values from contiguous region

Retrieving Partial Data

- (*) `INTEGER_ELT` - return c value (`int`, `double`) for single data element
- (*) `INTEGER_GET_REGION` - populate provided buffer with values from contiguous region
  - Copies data so not ALTREP destructive

How Not To Talk To ALTREPs

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- `ITERATE_BY_REGION_PARTIAL(|0)`
  - Same as above but specify starting position and count

An Example - `which` Internals

(Part of) the C code implementing the `which` R function:

```
int ioffset = 1;
int *buf = (int *) R_alloc(len, sizeof(int));
/* use iteration macros to be ALTREP safe <snip> */
ITERATE_BY_REGION(v, ptr, idx, nb, int, LOGICAL, {
    for(int i = 0; i < nb; i++) {
    if(ptr[i] == TRUE) {
        buf[j] = ioffset + i; // offset has +1 built i
        j++;
    }

    }
    ioffset += nb; // move to beginning of next buffer
});

len = j;
// buf has ints in it and we're returning ints, <snip>
PROTECT(ans = allocVector(INTSXP, len));
```

Example ALTREP packages

https://github.com/ALTREP-examples

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- Luke Tierney
- Michael Lawrence
- Tomas Kalibera
- Mike Smith and Bioc Devel Forum
- You

Full List of ALTREP Methods

ALTREP Class Methods (All ALTREP Types)

- UnserializeEX
- Unserialize
- Serialized_state
- DuplicateEX
- Duplicate
- Coerce
- Inspect
- **Length**

ALTVEC Class Methods (Vectors)

ALTREP methods, plus

- **`Dataptr`**
- `Dataptr_or_null`
- `Extract_subset`

ALTINTEGER, ALTREAL Class Methods

ALTVEC methods, plus

- `Elt`
- `Get_region`
- `Is_sorted`
- `No_NA`
- `Sum`
- `Min`
- `Max`

ALTLOGICAL Class Methods

ALTVEC methods, plus

- `Elt`
- `Get_region`
- `Is_sorted`
- `No_NA`
- `Sum`

ALTRAW/ALTCOMPLEX Class Methods

ALTVEC methods, plus

- `Elt`
- `Get_region`

ALTSTRING

ALTVEC methods, plus

- `Elt`
- `Set_elt`
- `Is_sorted`
- `No_NA`